AD-A253 393

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REPORT

FINAL REPORT

Evaluation of Lightweight and Low Profile Communications Devices for Respiratory Protective System 21 (RESPO 21)

To

U.S. Army Chemical Research, Development, and Engineering Center

February, 1992

CBIAC

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FINAL REPORT

Contract: DLA 900-86-C-2045
TASK 202

on

Evaluation of Lightweight and Low Profile Communications Devices for Respiratory Protective System 21 (RESPO21)

to

U.S. Army Chemical Research, Development, and Engineering Center
Aberdeen Proving Ground, MD 21010-5423

February, 1991

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INTRODUCTION

The Chemical Research, Development, and Engineering Center (CRDEC) is entering development of the next generation of respiratory protection (RESPO 21) to replace the current M40 series of protective masks. One of the design goals of this development is to improve both face-to-face and electronic communications while wearing respiratory protection. Commercial voice amplification systems being evaluated for this application are too bulky for many field applications. An evaluation of miniaturized communication systems was needed to expand the potential applications of voice enhancement.

OBJECTIVES AND SCOPE

The overall objective of this task was to evaluate techniques for miniaturizing personal communication systems. The definition of "communications" in this project was confined to hearing and speaking, and did not include other forms of transferring speech such as radio.

Specific objectives for this task were modified twice after initial establishment. The original objectives were to first generate a number of concepts for communication system functions and components, then to select three of these concepts for experimentation and demonstration.

The first modification of the objectives were contained in an extension to the task contract, which specified the additional function of amplified listening/overpressure protection and the additional design consideration of operation during power-down.

The final modification of the objectives was the addition of an upgrade to a stereolithography apparatus interface package as a deliverable, with the deferral of certain aspects of the electronic communications system study to the 1991 contract on the same subject.

Deliverables from this project were:

- Monthly technical progress reports
- Discussions and meetings with the POC upon request
- Demonstration model components for communications systems
- A demonstration model integrated amplified hearing and speech system, which included automatic level control and noise filtering

- The upgrade to the stereolithography apparatus interface, with fully paid license

- This Final Report.

All deliverables have been fulfilled with this report.

The scope of the work was limited to analytical and laboratory investigations. Demonstration model devices and the demonstration integrated hearing and speech system were for the purposes of laboratory investigation only, and are not represented as being suitable for field trials.

TECHNICAL INVESTIGATIONS

Requirements and Assumptions

In the army's new design for a lighter weight, tighter fitting gas mask, there is a need to provide an active communication system. The mask itself, as well as internal and external noise sources, provide a substantial barrier to normal communications among personnel outfitted with the mask in typical operating scenarios. Specifically, since the mask covers a considerable portion of the soldier's head, the mask structure provides a barrier to normal conversation. Under quiet conditions, it is likely that voice communications would be audible, albeit somewhat muffled. However, typical operation scenarios are far from quiet. Rather, conversations, even without the mask, are hampered by ambient noise from diesel engines (as is the case for personnel in armored tanks) or gasoline engines and rotor blades (as is the case for personnel in helicopters). With the gas mask in place, the problem becomes worse, especially for the new generation of masks, which feature active air flow and a constant internal positive pressure from a fan that generates its own level of noise. Hence, in order to maintain vital communications among the personnel and still maximize their freedom of movement within these operating environments, a self-contained voice communication sub-system must be employed into the overall gas mask system.

Primary design considerations for such a system include:

- Methods for output matching an integrated communication system to field, combat, and aircrew electronic systems.
- Methods for optimizing the performance of passive (power down) speech transmission performance such as floating diaphragms and multi-frequency response based on acoustic design information.
- Methods for improving hearing in a high noise environment while preventing noise damage from instantaneous spikes and/or overpressure. (i.e., noise canceling)
- Methods for optimizing passive (power down) hearing both with and without the helmet.
- Methods for integrating the miniaturized personal communication system, hearing assist/protection, and electronic communication.
- Component location to maximize output performance while maintaining critical compatibility interests.

Note that some of these issues fall outside the realm of the electronic investigation. Other technical requirements for the audio communications facilities are derived from the mask attributes which may interact with those facilities.

Mask concepts can be generally separated into those with rigid facepieces and those with conformal facepieces. Rigid facepieces provide several benefits for communications provisions, most notably space and support for mounting components, and also a degree of acoustic isolation between the inside of the mask and the outside. Such separation is required for several of the preliminary communication equipment concepts. Conformal masks may be required to have areas which are modified to support communications components.

Another requirement which impacts communications concepts is the time limit on donning the mask. There are different levels of "donnability" for the communications gear, but under no circumstances can they impede putting on the mask. Ideally, the communications gear is "invisibly" integrated with the mask, so as soon as the mask has been put on the communications components are fully aligned and operational. A second level of donnability is demonstrated by designs which may require some manual alignment or adjustment after the mask is put on. Such alignments would be made through the (flexible) wall of the mask, and would not compromise the mask's protection value. In the third level, the user must attach communications components to the mask after donning it. This is expected for optional items such as connections to intercoms, but is otherwise of lower desirability than the first two levels.

Concepts

The Battelle project team generated and presented a group of concepts to the POC during a visit to Battelle. Brief descriptions of these concepts are provided below. All of the following concepts assume the general framework of an amplified speech and hearing system integrated into the mask. The first group of concepts are approaches for implementing components of such a system, and the second group are approaches for the functional design and operation. In parentheses following the title for each concept is an indication of whether the concept applies to the speaking or listening portion of the voice communications system.

- PVF2 Earphone (listening) -- in this concept, a ring around the ear in the headpiece supports both a piezoelectric film and a removable rigid cup. Positive air pressure in the mask creates and outward bow in the film, while a small hole in the outer cup relieves any trapped air. The film in this arrangement acts as a speaker when excited by an audio frequency electrical signal. The outer cup acts as a sound barrier, permitting the amplified listening system to control the sound amplitude. For power-down operation, the outer cups are removed, and the unpowered film acts as a diaphragm to permit passive hearing.

- PVF2 Microphone (speaking) -- a strip of piezoelectric polymer held against the mastoid bone would pick up a reasonably good voice signal, and would be completely away from the relatively congested front of the mask. It could be very flat, and since it is flexible it would be relatively comfortable. This microphone would not interfere with donning the mask, but might require some adjustment through the wall of the mask after donning.

- Phased Array Speaker (speaking) -- directivity can be achieved only with an aperture larger than the wavelength of the sound, which would require a 1 foot diameter speaker for 1111 Hz, for example. Clearly such a speaker would not be feasible in the mask. It might be possible, however, to achieve a degree of lower-frequency directivity using an array of smaller speaker elements, perhaps mounted on the bib area of the mask. If it works, this arrangement would require the speaker to turn the bib, and thus the entire upper torso, toward the intended recipient, which isn't as easy as turning just the head.

- Automatic Gain Control (listening) -- in amplified listening the setting of gain could be performed manually. However, there are two basic problems with manual control: the first is that a constant need to change gain would be a burden on the soldier, and the second is that the gain control potentiometer would be a reliability problem. AGC would solve both of these problems. Also, if the response can be made fast enough, AGC would perform the amplitude limiting function as well. (Note the difference between automatic level limiting and automatic gain control.) The primary concern with AGC is the user's ability to process audio information which has, to a large extent, had the amplitude information removed.

- "Graphic Equalization" (speaking) -- the sound emitted by an amplified mask is a combination of the sound carried mechanically by the mask structure, including the voicemitter, and that produced by the electronic equipment. Typically, the mechanical path is better at transferring lower frequencies, while the electronic is better at higher frequencies. This combination could be exploited by first designing the resonances out of the mask, then designing the gain vs frequency characteristics of the electronic path to complement the mechanical path. Simple gain vs frequency curves can be implemented with the design of the amplifier and speaker, but more complex curves may require a multiband variable attenuator, a.k.a. a graphic equalizer. Integrated circuits which perform this function are currently available.

- Active Noise Cancellation (listening) -- with sufficiently fast signal processing, any repetitive noise source can be effectively removed from an audio signal by adding its inverse. Candidates for removal in this fashion might include helicopter rotor noise. This would be a complex function, requiring both significant development and extensive testing. Demonstration, even in relatively simple form, is beyond the resources of this project.

- Adaptive Notch Filtering (listening) -- if the spectral characteristics of a primary noise source (such as a turbine engine, for example) are known, they can be selectively filtered from the amplified listening signal. Even if only a single frequency can be notch-filtered in this fashion, it may provide a significant relief for the soldier while still permitting hearing in both higher and lower frequencies. The spectral or frequency information might be provided externally (derived from a tachometer signal if source is an engine, for example) or it may be derived from the audio signal itself. The greatest need for this concept is knowledge of spectral characteristics for the major noise sources. As with the adaptive noise cancellation, the needs for R&D and testing of this concept are beyond the resources available for this project.

- Simple Notch Filtering (listening) -- in a complex noise environment, where there are high-amplitude noises across a very wide range of frequencies, the use of a fixed notch filter to attenuate all but normal voice frequencies would provide some degree of benefit for listening to speech. This would be simple to implement, but the primary concern is the degree of benefit it would provide in different noise and task environments.

All of the concepts were of interest to the POC, and in discussions with Battelle the following were selection for inclusion in the demonstration model devices:

- PVF2 Earphone
- PVF2 Microphone
- Phased Array Speaker

and in the integrated amplified hearing and speech system:

- Automatic Gain Control
- Simple Notch Filtering

All of these were investigated, and the results are presented in the following section of this report. Active Noise Cancellation technology was of great interest, but was deemed beyond the scope of this project. Other DoD agencies, including Army CECOM and the Air Force ASD, are funding development and procurement activities in this area.

Laboratory Analysis

The device investigation focused largely on the voice detector and emitter (i.e., the microphone and speakers) and their associated interface circuitry. The consideration of detectors and emitters was largely limited by those concepts having the greatest potential for incorporation into the gas mask design. Thus, emphasis was placed on relatively small, flat elements. Flexibility of the element was also considered, but it was not regarded as critical to the operation. In addition to the physical characteristics, the ability to detect and reproduce audible speech were regarded as critical. Frequency response, electrical interference, acoustic interference, and general audibility were examined for different elements and circuit configurations.

To provide a baseline for initial evaluation, the characteristics of conventional technology were examined. Demonstrated and projected characteristics of the experimental devices were compared with these baseline levels to develop recommendations for further study.

Conventional Technologies

In general, the best acoustic response was obtained with commercially available, conventionally employed components, such as electret microphones and moving coil speakers. These devices are typically used in audio applications, and with some signal amplification, they provided a straightforward means of implementing a stand-alone communication system. The reproduction of speech was quite audible; the presence of electromagnetically generated noise (primarily 60 Hz and its harmonics) was nearly absent, and the microphones were generally not sensitive to motion or to vibration, tapping, etc. except at the sensing end of the element. Aside from an amplifier having a gain of 100 or so, little or no additional signal processing was needed to generate an audible signal at the output.

However, the electret microphone and moving coil speaker may have physical limitations when considered for the gas mask application. Speakers come in a variety of sizes, some of which may only be two to three inches in diameter and have flat (as opposed to cone-shaped) acoustic surfaces. But, they all must have appreciable depth dimension due to the permanent magnet/moving coil assembly. As the acoustic emitter in the gas mask, the speaker will be a component of the head piece and placed near the user's ears. Depth dimensions are critical in this area, since the user may likely need to wear other protective head gear suited for the mission, i.e., a helmet. Interference between the mask and helmet, as well as other clothing and equipment, must be minimized.

Electret microphones can be quite small, with dimensions on the order of 1/2 inch diameter and 1/2 inch long being typical. As the acoustic detector, this device would be mounted near the mouth of the operator. Again, the depth dimension may be important to the mask design, but it is does not present the interference problem that the speakers do.

The mask assembly, which includes the head piece and a chest bib, will actually house two self-contained acoustic systems for bilateral communications. It is likely that one half of each system (a detector and two emitters) will be placed in the mask area, while the other halves of each system and the supporting electronic circuits will be housed in the chest bib. Furthermore, given that the design constraints on the acoustic components placed in the bib are less stringent than those in the mask, a conventional technology, could be used in the bib.

Alternative Technologies: Piezoelectric Devices

To meet the requirements imposed by the mask design, alternate technologies were considered. Other than electromagnetic or capacitive devices, the most logical and typically employed technology for these kinds of applications are piezoelectric materials. In this project, a piezoceramic annunciator and several configurations of piezoelectric polymer film were examined for the gas mask application. In general, piezoelectric devices have the advantage of extremely flat structure and low power consumption.

The acoustic volume generated by piezoelectric devices is a function of their geometry, input signal amplitude, and operating condition. Extremely loud output can be generated when the element is operated at a **resonance** frequency, but under broadband conditions, the volume is considerably lower. Within practical limits, increasing the voltage applied to the element can increase the acoustic output. For piezoelectric polymers in particular, hundreds of volts can be applied across the terminals of the element, but generating signals of this level is another issue. For this application, the structure of the element is the most practical variable and was the parameter explored in depth during this study.

These same devices can be used as acoustic detectors. In fact, to some extent, identical configurations can be employed as either speakers or microphones. Generally speaking though, piezoelectric ceramic devices are more efficient than their polymer counterparts at generating acoustic signals, and polymer-based devices make better detectors.

Piezoelectric Speaker

From a series of tests conducted on piezoelectric devices employed as emitters, a flat piezoelectric ceramic speaker purchased from Radio Shack (Archer model number 273-091) produced the most reasonable output. The unit makes a fair earphone, reproducing audio signals down to 300 to 500 Hz and up to 10 kHz or so. Distortion is readily apparent when the signal gain is increased too high, and even at moderate input signal levels, a modest amount of distortion is detectable. However, much of this distortion can be reduced by preloading the center of the element with a firm but resilient material and moderate pressure. In particular, a piece of polyurethane foam material was placed in the center of a sheet metal lid and the piezoceramic element was then pressed into the lid. As pressure was applied, much of high frequency distortion was eliminated, allowing the lower frequencies to be more readily observed. When the applied pressure was increased, the prominent effect was a reduction in acoustic volume.

Several devices fabricated with the piezoelectric polymer film polyvinylidene fluoride (PVDF) were constructed and tested. The efficiency of acoustic emitters was generally maximized when the film was curved and held fixed only along the straight edges. Since the electrically imposed stress on the polymer produces a strain that is most noteworthy along its planar dimension, bending the film tends to exaggerate the acoustic motions of the element. The piezoelectric strain along the planar direction translates into a motion that longitudinally compresses the air in front of the element normal to the element surface. The net effect is the same as that of a moving coil speaker. When the film is flattened, the effect of the strain is reduced, and consequently the acoustic output greatly diminishes.

The output is also impeded when the film is bonded to a rigid backing or placed against another material. In an attempt to maximize the effect of device curvature, an experiment was conducted where a long, thin strip of polymer was loosely coiled with a polyurethane sheet. The film was roughly 18 inches long and 1/2 inch wide, and the urethane sheet had roughly the same dimensions and was approximately 1/4 inch thick. The film was placed on the foam and rolled into a disk shape having rough dimensions of three inches in diameter and 1/2 inch thick. While the film in an unrolled, unbacked state produced some audible output, little or no output could be discerned from the fabricated structure.

As predicted, thinner films seemed to generate a greater acoustic output than thicker films, and elements having larger film areas produced louder outputs than smaller devices. The film thickness largely affects the size of the electric field imposed across the film. For the same input signal, the electric field across a 9 micron thick film will be roughly three times larger than that across a 28 micron film. Furthermore, the physical response will be proportionately greater for films having the same area. As the size of the element is increased, the absolute value of the response is proportionately larger. Hence, acoustic output is maximized with thin films having large surface areas (assuming all other factors are equal) and formed into a curve.

The range in the radius of curvature where the film produces an audible output is rather broad. According to Atochem North America, the suppliers of the piezoelectric film, there is supposedly an optimum curvature to maximize the output, but from the experiments conducted here, the optimum point can have considerable variability without significantly hampering the response of the element. However, it was quite clear that approaching a flat geometry greatly affected the output. For the gas mask application, the curvature would lead to a significant depth dimension, and the surface areas required to achieve reasonable acoustic volumes are prohibitively large. These requirements have obvious drawbacks in the mask design.

As a point of reference, Atochem has demonstrated an acoustic speaker at trade shows using PVDF. With some amplification of the signal received from the earphone terminals of a typical transistor radio, a relatively small but audible signal was generated with a device having dimensions of roughly five inches by ten inches. Based on this observation and the results of testing in the laboratory, it recommended at this time that the piezoelectric film not be considered for use as the earphone elements in the gas mask.

Piezoelectric ceramic annunciators operated as earphones for the gas mask seem to be adequate for emitting voice signals to the operator's ears. The elements make poor wideband speakers, but when held in close proximity to the ears, voice signals reproduced by these devices are quite audible. Response is further enhanced by applying a preloaded stress to the ceramic element; resonances that generate warble in the output are subdued, and the bass response seems to improve slightly. Nonetheless, care must be taken not to overdrive the element, as distortion is sure to occur.

Signal Processing Circuitry. To gain the greatest effectiveness from the piezoelectric element, the signal processing circuitry should have a high input impedance. Field-effect transistor (FET) amplifiers/buffers or operational amplifiers with a FET input are preferred. A National Semiconductor LH0022CD op amp served this purpose. The device was configured as a non-inverting amplifier with a gain of approximately 30, and the input terminal was shunted with a one megohm resistor. According to Dr. Park at Atochem, shunting the piezoelectric element with a high resistance reduces the amount of signal drift observed at the output of the amplifier. The value of the resistor is determined by the capacitance of the element and the high pass roll-off frequency of the system. In this case, the element had a capacitance of a few nanofarads (3-10), depending on the size of the element, which coupled with the resistance to produce a roll-off frequency of approximately 30 Hz. If a lower roll-off is desired the resistance can be increased, but for this application it is probably not necessary.

The output of the high-impedance amplifier was delivered to a Krohn-Hite filter (model number 3202R) configured as two high pass filters wired in series with a cut-off frequency of 300 to 500 Hz. The high pass filter had a roll-off characteristic of 48 dB per octave (24 dB per octave per filter stage) and maximum stopband attenuation of 80 dB. This configuration was designed to effectively attenuate most of the 60 Hz noise and its first several harmonics coupled by the detector element and the bread-boarded amplifier. (Laboratory-style prototyping boards are notorious for their capacitive coupling and ability to couple radiated noise.) The output of the high pass filter was then delivered to two Frequency Devices low pass filters/amplifiers (model number 901F) connected in series. Each low pass filter was initially by-passed and only the amplifier stages, which were set for a total gain of 20 dB (gain of 10), were employed in the set up. The output of the filter/amplifiers was then delivered to a 4-inch diameter moving coil speaker.

After conducting several tests on the element's ability to pick-up voice signals, it was observed that the frequency response rolled-off significantly above 4000 Hz. Since annoying high frequency noise could be detected at the speaker output, the Frequency Devices units were set to pass signals with frequencies below 5000 Hz. This appeared to diminish the noise content without affecting the audibility of the speech signals.

Some lower frequency noise due to the harmonics of the 60 Hz EMI could be heard. In particular, a signal at 300 Hz was somewhat annoying and could be filtered out by setting the high pass filter stage to 500 Hz, but to some extent this had an adverse affect on the audible signals. Further increases the high pass filter frequency were critically detrimental.

While the piezoelectric element--with appropriate signal processing--adequately detected voice signals, it demonstrated extreme sensitivity to mechanical perturbations. Rubbing or tapping the surface of the element or the sheet metal substrate produced a dominating output signal. For much of the testing, the detector was carefully hand-held or placed on a resilient surface to reduce the impact of these extraneous stimulations to the piezoelectric element. However, despite its apparent sensitivity to these perturbations, the element seems relatively immune to breath noises that are common with conventional microphones when they are held close to the mouth.

Recommendations. In the final configuration, it is recommended that the gas mask detector element be formed into a bimorph, as described above, to minimize interference from electromagnetic sources. The signal conductor from the detector element to the processing circuit should be a shielded cable, and the circuitry itself--particularly the high-impedance amplifier--should be housed in a shielded container. By reducing the amount of EMI coupled by the detector and input amplifier, it may be possible to eliminate the high pass filter from the system.

Mechanical disturbances to the detector may be minimized by incorporated a resilient mounting for the sheet metal substrate. Latex rubber or other flexible material around the substrate would likely be adequate and could be designed directly into the mask structure. Furthermore, if a passive voice communication system is desired as a backup, holes could be put through the sheet metal substrate and even the element itself, if necessary.

Sometime after Battelle completed its laboratory investigations of piezoelectric polymer microphones, the project team was contacted by Litton Data systems. They reported a similar development, which they pursued through the point of beginning a limited production run. The application which they were apparently designing for was an underwater use. Their design, from descriptions they provided, somewhat resembles a condenser microphone in both physical configuration and the inclusion of an amplifier in the microphone.

Speaker Array

One of the concerns in implementing amplified speech in the RESPO21 communications system is the size and weight of the speaker. Producing a given volume level required at a given distance, plus an audio spectrum response required for intelligibility, could result in an overly high power requirement which would, in turn, drive the size of the speaker and battery up. Making the speaker more directional might offer a tradeoff between lower total power output and breadth of coverage. In some circumstances, the selectivity of a narrower audio beam might be advantageous. One significant problem with using a typical directional speaker, such as a horn, is that it's width must be greater than the wavelength of sound to be shaped. Since the wavelength of a 1111 Hz tone is 1 foot, and frequencies considerably lower than that are important for intelligibility, using a horn is not feasible for a personally carried device.

An alternative might be to use an array of smaller speakers driven in phase to produce the effect of a single larger speaker. To test this approach, we fabricated a four-speaker array with a grid spacing of 1 foot. The speakers were connected to produce in-phase signals. A fifth speaker, identical to the four in the array, was mounted on the same base for comparison. The array and the single speaker were driven by a signal generator at several frequencies, and the spatial distribution of the sound pressure levels measured using a sensitive meter. What we expected to see was evidence of beam shaping as the driving frequency's wavelength approached the grid spacing, and that is what the results showed. Copies of 6 graphs are attached to this report; note that these are polar plots of angle from centerline versus sound pressure level at a fixed distance, not iso-db maps.

The six graphs are for the single speaker and the four-speaker array, each at three different frequencies. The first frequency, 500 Hz, has a wavelength more than twice as long as the array spacing, and so would not be expected to show any beam shaping beyond that provided by the single speakers. Graph #1, however, appears to show a slight amount of shaping, which is probably due to the simple superposition of the four speakers' output. Graph #4 shows the output of a single speaker at 500 Hz, which is very uniform. As the frequency is increased, first to 1000 Hz as depicted in graph #2 and then to 2000 Hx as depicted in graph #3, the beam shaping becomes much more pronounced.

A comparison of graphs #1, 2, and 3 raises a concern about the use of a phased speaker array. An array will tend to distort voice signals since it sends different amounts of energy, depending on the frequency, to different regions. Since the intelligibility of a voice signal depends on accurately reproducing the entire spectrum of audio frequencies, this differentiation by frequency may diminish intelligibility. Informal experimentation with the array supports this concern, with the observers reporting that the voice changed in amplitude as the array was turned and sounded "odd" when off-axis. It was still quite intelligible, however.

For the RESPO21 voice communications system, the use of multiple small speakers is still attractive for its ability to handle increased power output when needed, and for the robust performance offered by redundancy. Using deliberate speaker phasing to achieve a shaped audio beam appears less attractive, but the slight shaping inherent with closely-spaced multiple speakers is probably acceptable.

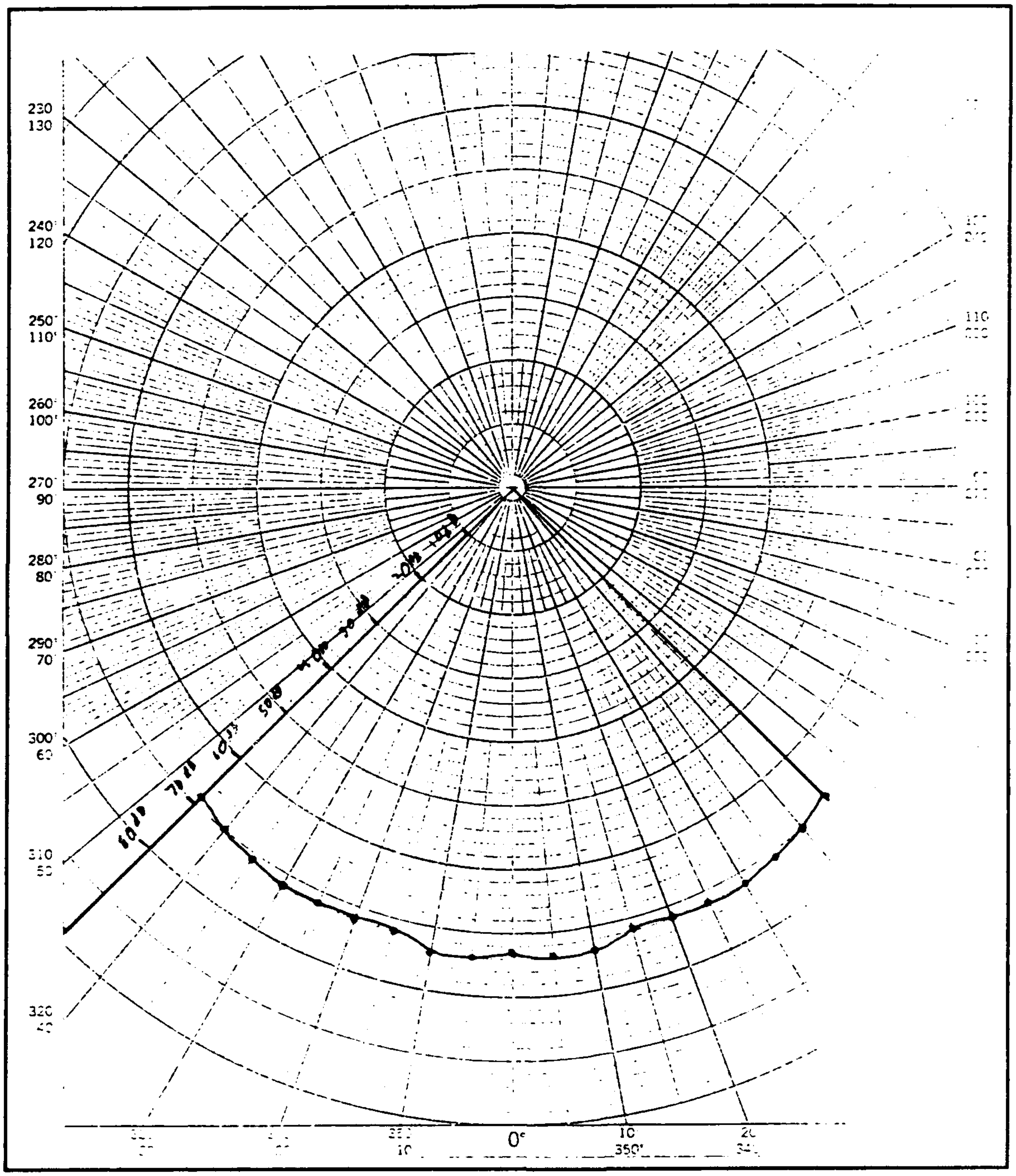

FIGURE 1. 500 Hz, Speaker Array, 2db for each Division

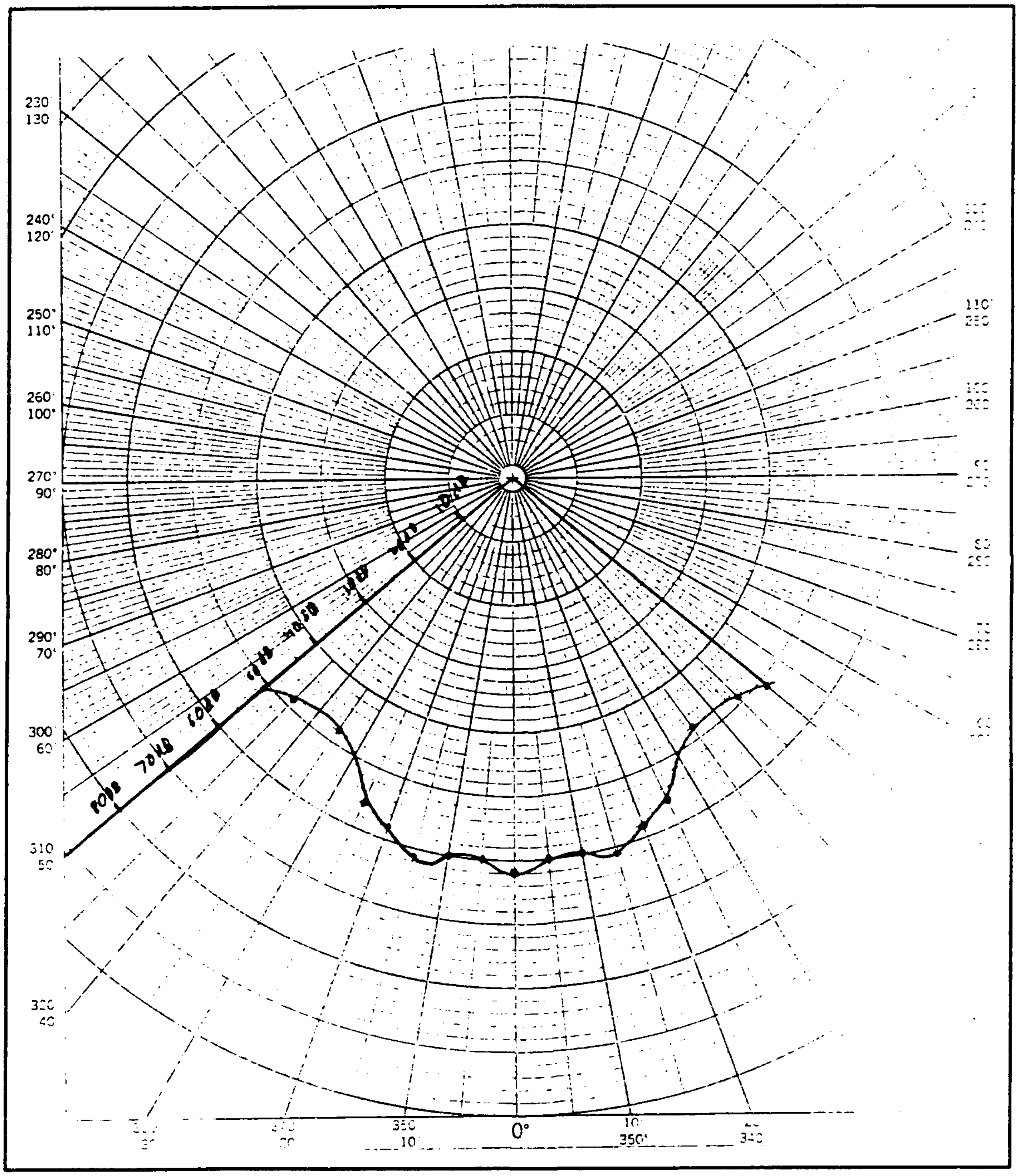

FIGURE 2. 1000 Hz, Speaker Array, 2db per Division

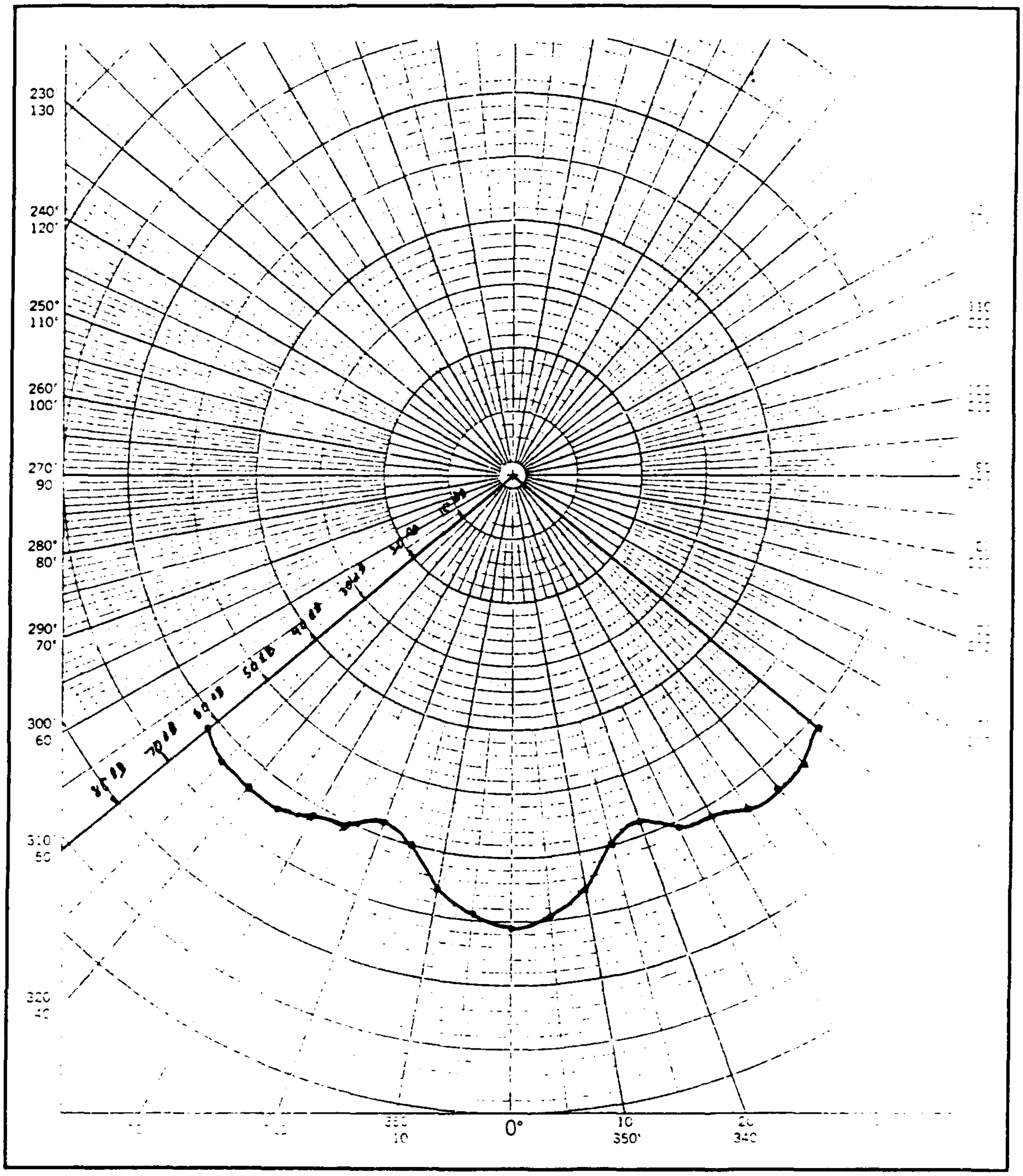

FIGURE 3. 2000 Hz, Speaker Array, 2db for each Division

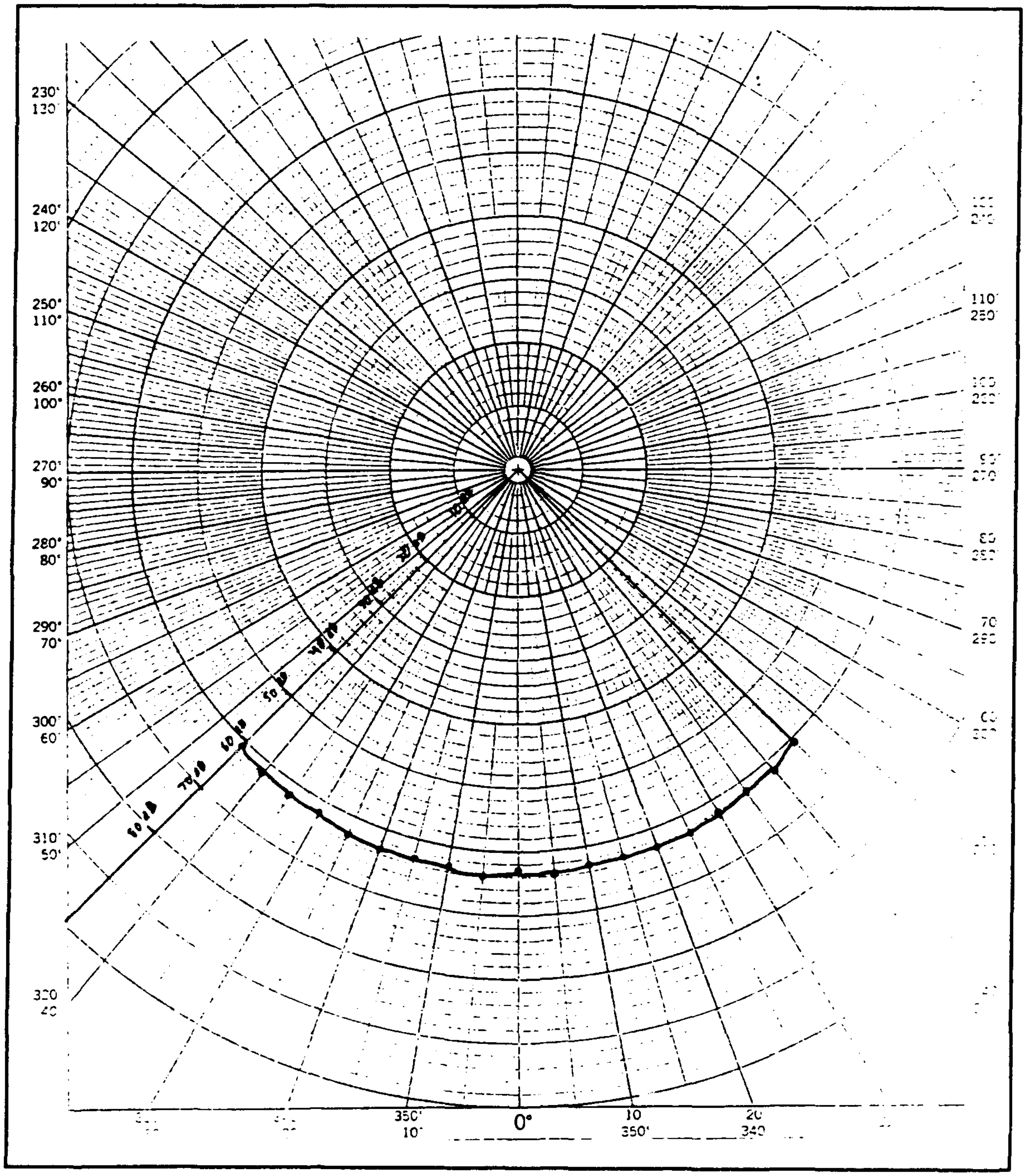

FIGURE 4. 500 Hz, Single Speaker, 2db for each Division

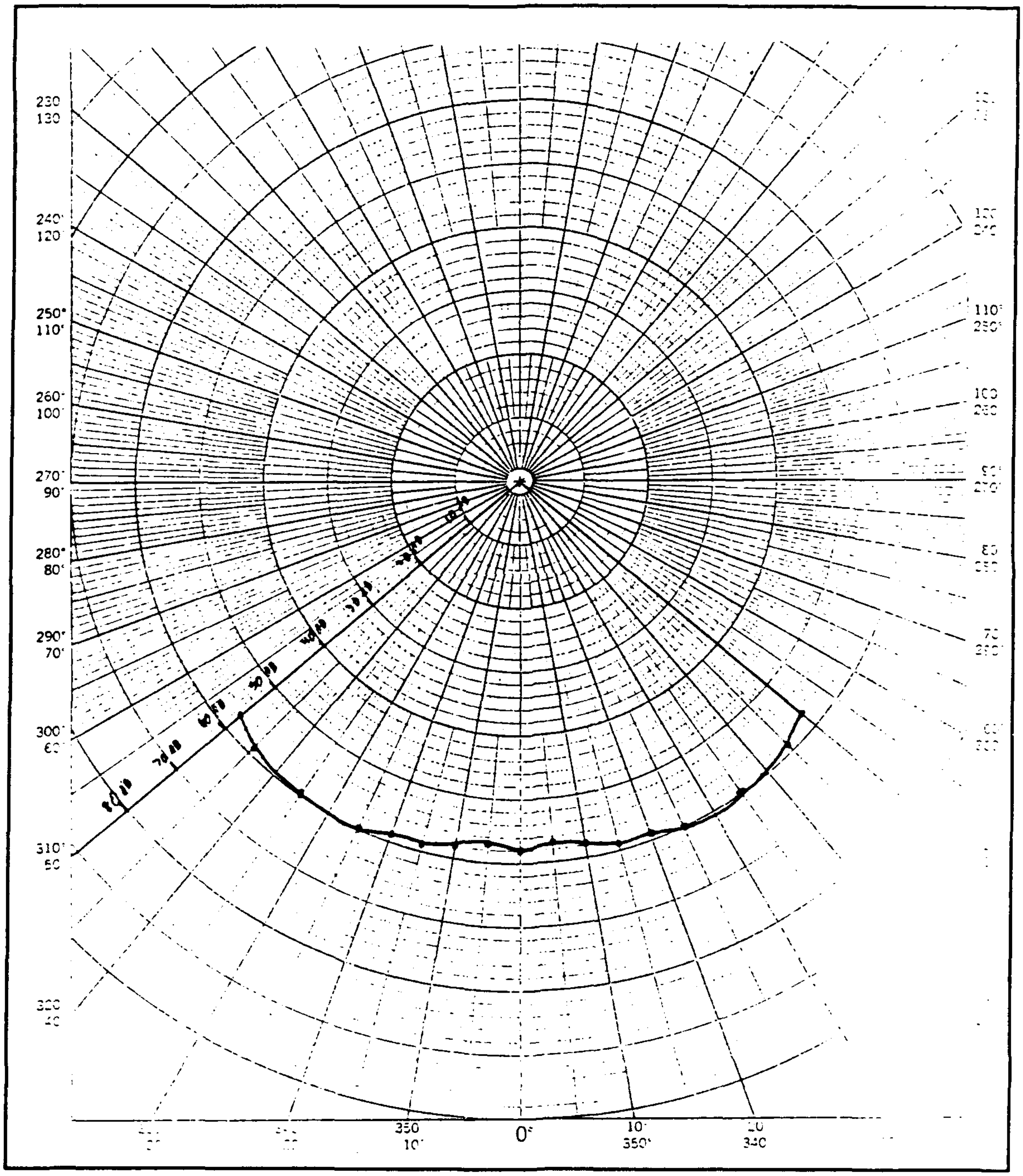

FIGURE 5. 1000 Hz, Single Speaker, 2db for each speaker

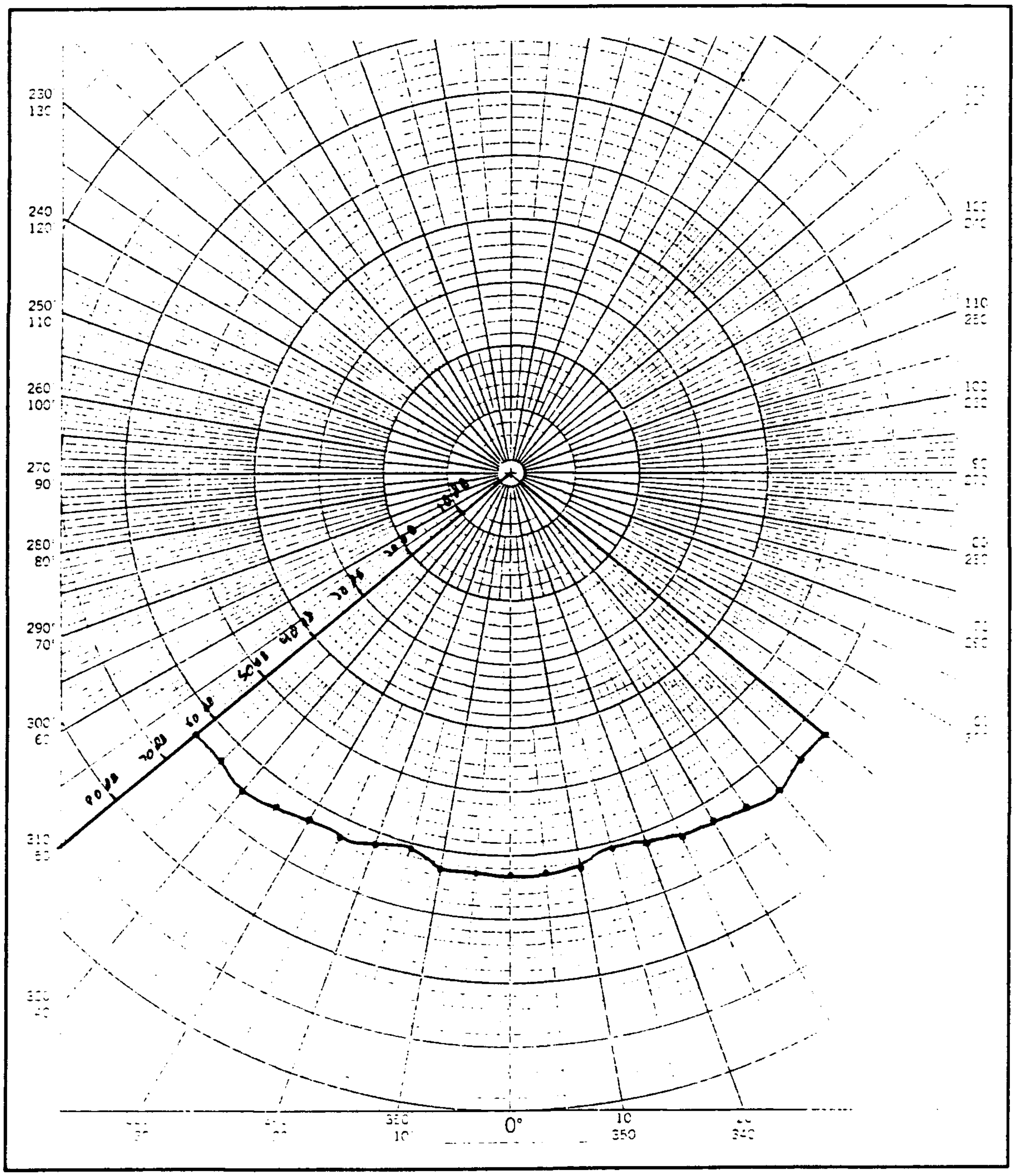

FIGURE 6. 2000 Hz, Speaker Array, 2db for each Division

Integrated Amplified Speech and Hearing System

An integrated system was built which contains an Enhanced Hearing portion and an Amplified Speech portion. The Enhanced Hearing portion, as shown in Figure 7, is a stereophonic amplified listening system with Automatic Gain Control (AGC) and a switch-selectable low-pass filter. The Amplified Speech portion, shown schematically in Figure 11, includes a microphone, a two-stage amplifier, and provisions for an external speaker.

The system is battery powered and portable, consisting of a headphone and an electronics module. Microphones for both listening and speaking are mounted on headphones which provide the output of the amplified hearing portion. The microphone for the amplified speech portion is a boom-mounted noise canceling type microphone, while those for the enhanced hearing portion are standard miniature condenser microphone elements.

Controls on the electronics module include:

- Power On/Off - controls power to both portions of the system
- Push to Talk - the amplified speech system is active only while this momentary-contact switch is pushed
- Filter In/Out - when this switch is in the In position the hearing circuit includes the low-pass filter
- Right and Left amplitude controls - these potentiometers, which can be operated with a small screwdriver, control the headphone volume.
- Center amplitude control - potentiometer control of the amplified speech volume.

Power for the system is provided by two 9V transistor batteries inside the case.

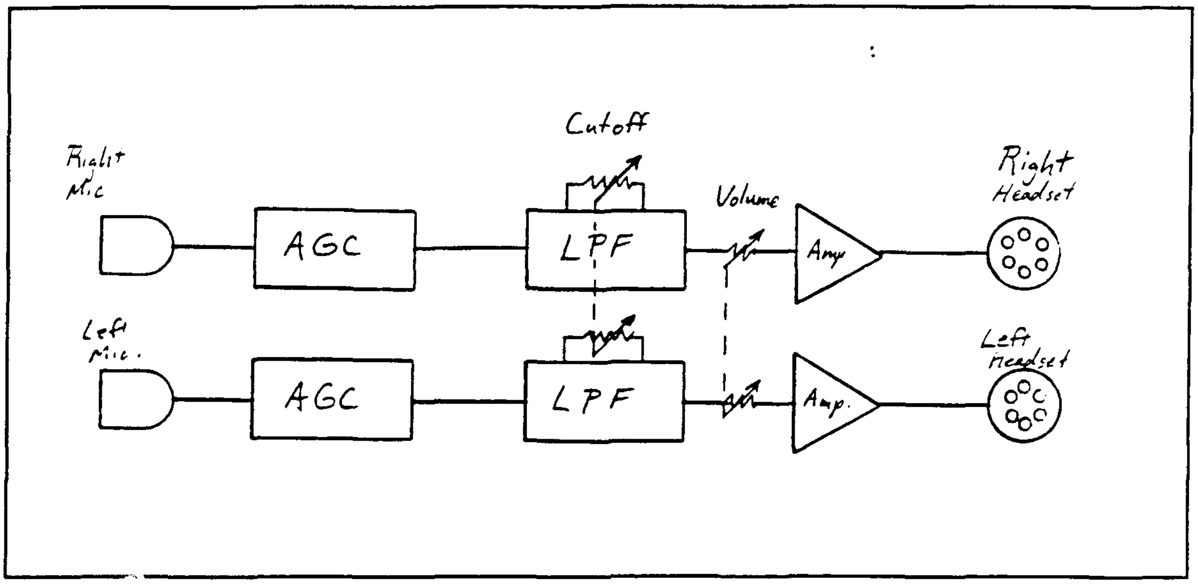

FIGURE 7. Enhanced Hearing

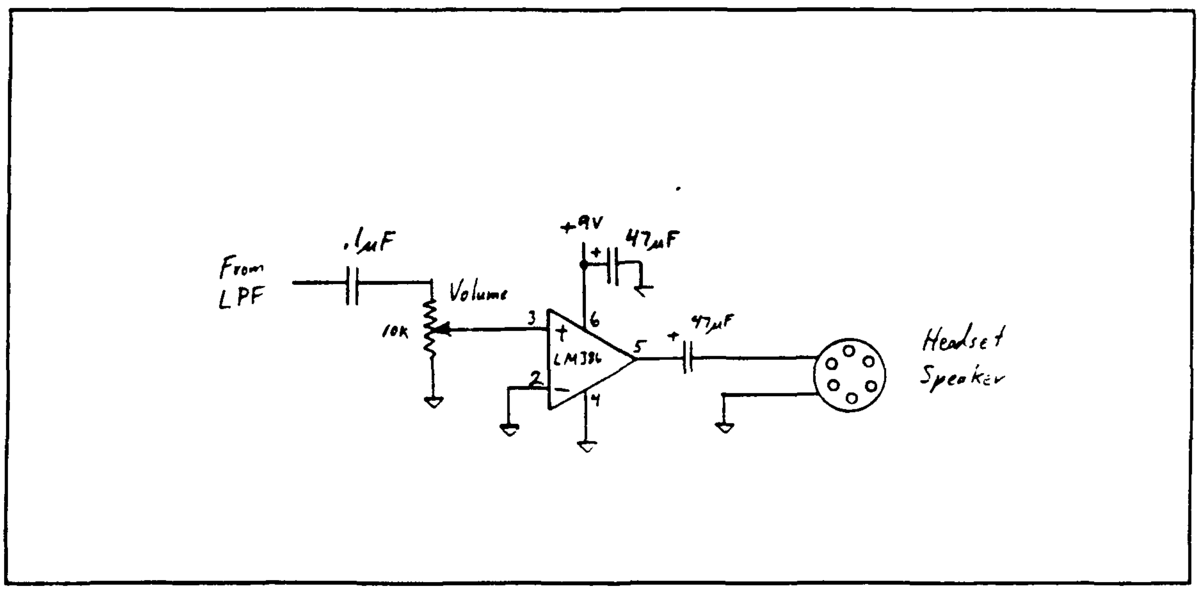

FIGURE 8. Headphone Amplifier

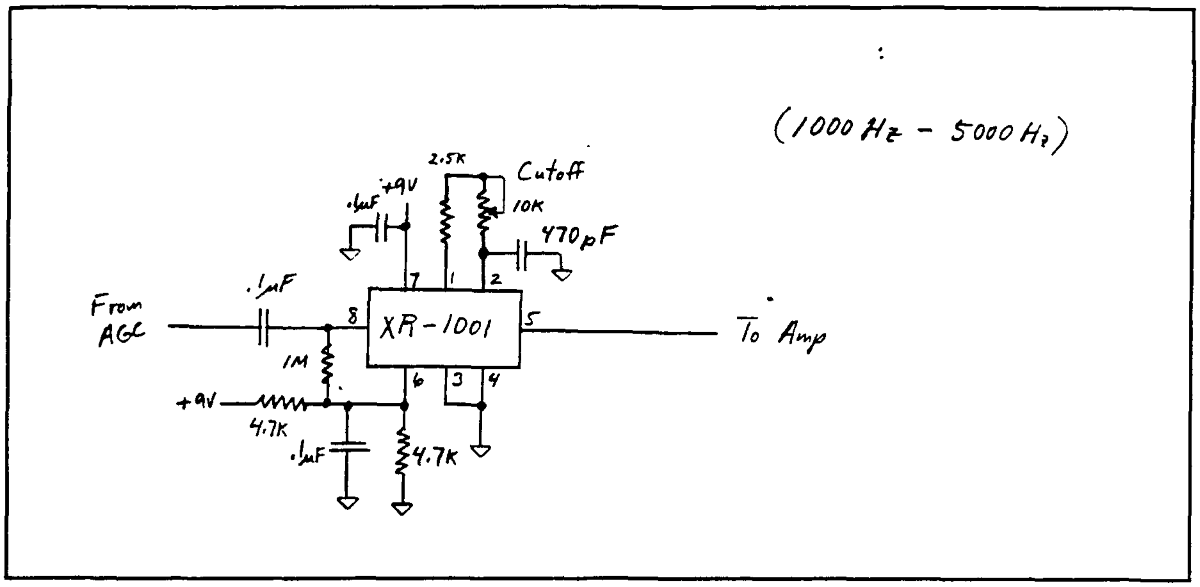

FIGURE 9. Low Pass Filter

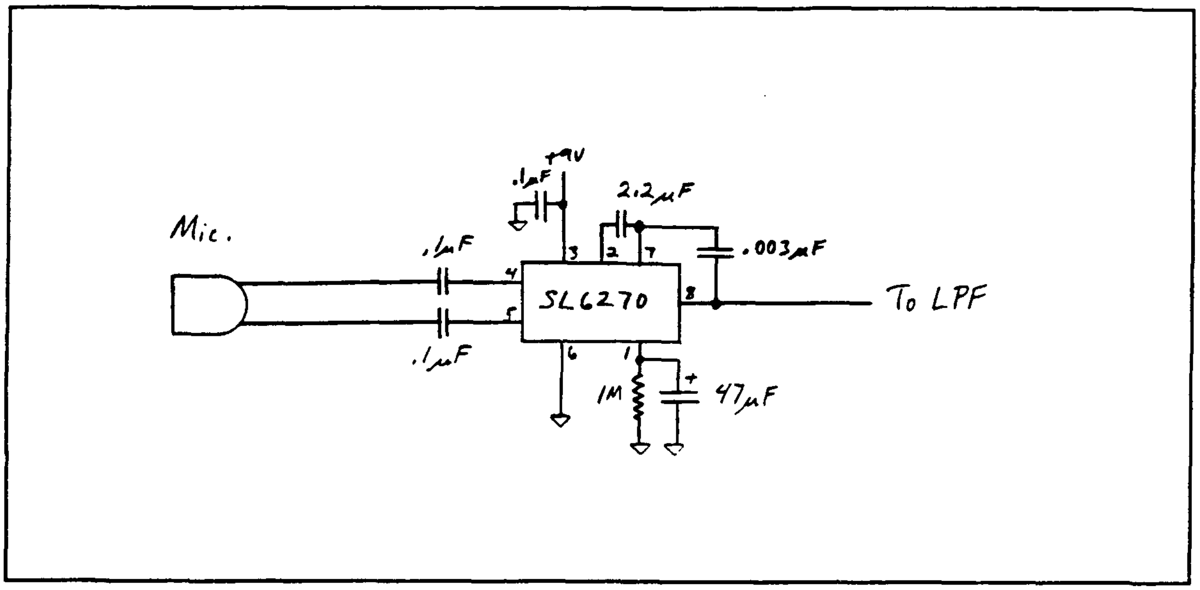

FIGURE 10. AGC/Preamp

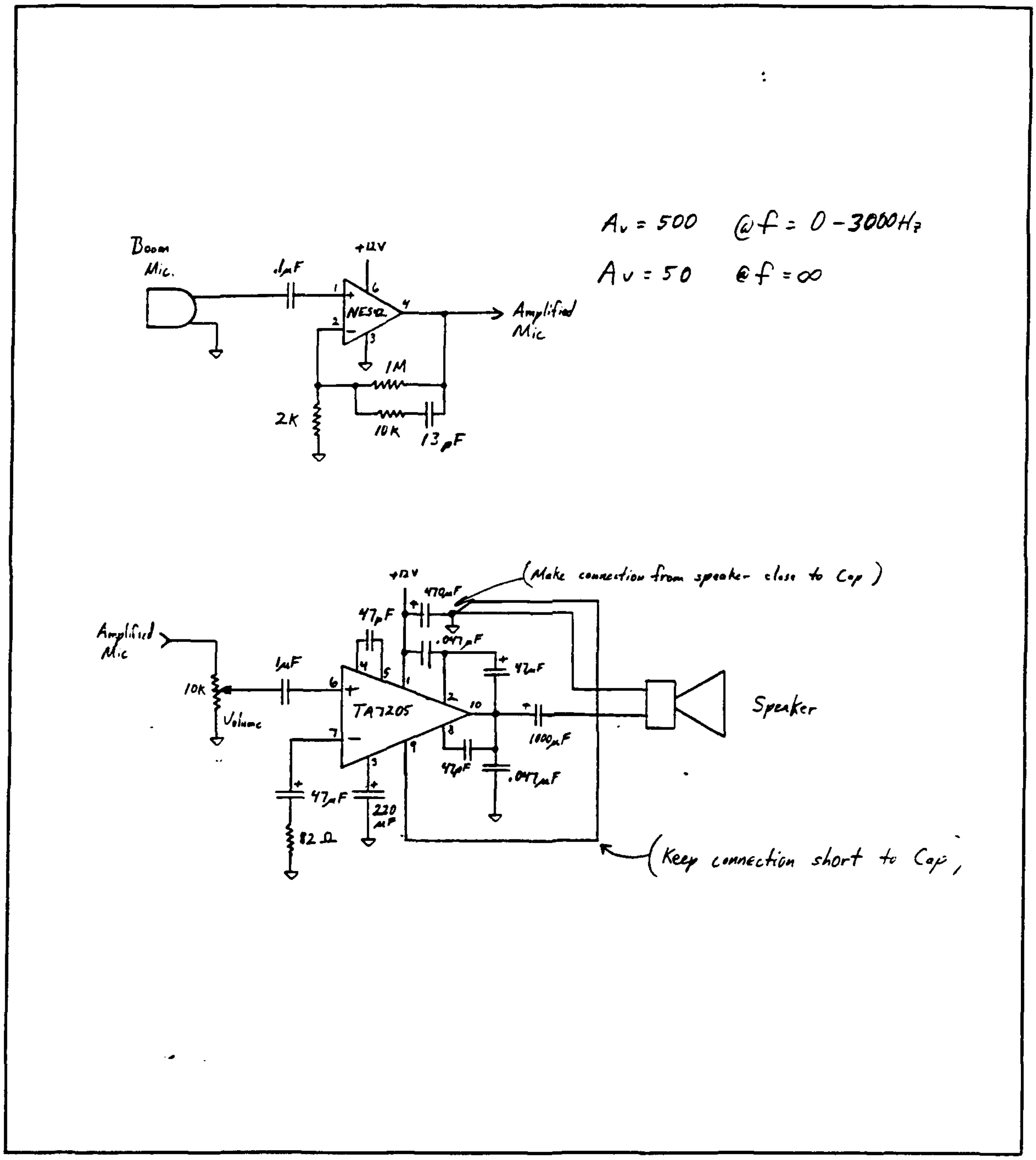

FIGURE 11. Amplified Speech

CONCLUSIONS AND RECOMMENDATIONS

In general, the results of the investigations indicate that there is good potential for a lightweight, miniature, battery-powered system in the RESPO21 ensemble which will improve the capability for both spoken communication and more general hearing. The following conclusions and recommendations are separated by the corresponding area of investigation.

Piezoelectric Speakers And Microphones

Specific conclusions on the piezoelectric speaker and microphone are more difficult to formulate. Both devices exhibited performance levels inferior to those of the conventional technologies, but the comparison is somewhat unfair due to the dissimilar levels of development. Also, the piezoelectric devices were significantly smaller and simpler than the conventional devices. It is quite possible that the piezoelectric devices could, with further specific development, be beneficial for the space-critical applications on and around the faceplate.

Because of their less stringent requirements, the emitter(s) and detector(s) employed elsewhere on the gas mask system, i.e., the bib area, can use more conventional technologies. The emitter in particular must be acoustically powerful enough to broadcast to other personnel in the immediate vicinity. Likewise, the detector must be capable of picking up signals from sources in a wide range of directions. These abilities are readily demonstrated by commercially available moving coil speakers and electret microphones.

Speaker Array

The use of a widely spaced array of speakers to achieve directional control of amplified voice output can not be recommended for use in the RESPO21 application. Given the limits on array spacing imposed by the size of the human, it would be difficult to avoid the unwanted spatial separation of the acoustic frequencies present in speech.

However, the use of multiple small speaker elements in a closely-spaced array appears to have some promise for increasing the power output while limiting the overall size of the emitter. Piezoceramic elements also appear to hold some promise for use in such an array, offering significant reductions in depth and weight compared to conventional moving-coil magnetic speakers.

Integrated Amplified Speech and Hearing System

The performance of the simple integrated system demonstrator was encouraging in its promise of significant capability enhancements with a small, simple, and inexpensive system. Some specific environments, such as flightline operations, will continue to need and drive the development of sophisticated Automatic Noise Cancellation systems. However, these systems are likely to remain beyond the cost limits for high-density deployment for a number of years.

Battelle's recommendations for the continuing development of the RESPO21 communications system have been incorporated in the plans for the 1991 activities, which are awaiting funding at the time of this report. Actions are expected to include refinement and size reduction of the electronic circuit, and further study of the following issues:

- Power-down operation -- It appears that a hood and faceplate structure which blocks the transmission of acoustic energy is desirable from the standpoint of controlling what the wearer hears, but it has definite drawbacks from the standpoint of power-down operation. To date, the preferred approach seems to be the use of removable barrier elements in the hood and faceplate, with diaphragms underneath to permit passage of sound if necessary.
- Interfaces to vehicle intercom systems and radios appears to be possible at the electrical signal level, but will require some form of converter module to accommodate differences in connectors and electrical signal levels and impedances. It would be both physically and economically difficult to include the converter modules in the RESPO21 electronics. An alternative approach is to mount them in the vehicle or on the communication equipment.

In summary, Battelle recommends that CRDEC continue to pursue the development of a miniaturized integrated voice communications enhancement to the RESPO21 ensemble.

APPENDIX A

David Sarnoff Research Center | Subsidiary of SRI International | CN 5300 | PRINCETON NJ 08543-5300 | 609-734-2000

October 31, 1990

Dr. Fred Renner
Battelle
505 King Avenue
Columbus, Ohio 43201

Dear Fred:

It was a pleasure to talk to you on Friday, 10/26/90, about the potential application for our piezoelectric acoustic device. We are definitely interested in exploring the opportunity to work with you and Battelle on the Army gas mask communication program. Attached, please find a somewhat generalized description of the device configuration that we developed for another application. It is the one that Vic Chatigny of ATOCHEM has evaluated. The basic design is flexible and can be configured in a variety of ways. However, the basic unit may be close to what is needed for the application. If this device is interesting to you, we should execute a Confidentiality Disclosure Agreement (CDA) between Sarnoff and Battelle, to cover the proprietary information on our devices, and on your application.

I look forward to hearing from you so that we can discuss the technical and business issues. I personally feel that it would be very enjoyable to work with you and Battelle.

Sincerely,

Charlie

Charles B. Carroll, Head
Electromechanical Systems Research
Phone: (609) 734-3030
Fax: (609) 734-2323

attachment

bcc: Brown, M.
Harris, B.
Leedom, M.
McCarthy, B.
Rodda, B.

Battelle Response

Our piezoelectric acoustic device is designed to function as a thin, stiffness-controlled vibrating diaphragm that is baffled and closely coupled to an acoustic cavity. The cavity should be about 10 to 20 cm^3, for the purpose of generating sound pressure levels of 100 to 110 dB (relative to 0.0002 dyne/cm^2) over the audio-frequency 500 Hz to 2KHz (for the current application). The acoustic device is 1" x 1" x 0.025" and requires 7.5 Volts rms. The electrical impedance of the transducer is capacitive and approximately equal to 15 nanofarads. The device is relatively light-weight and withstands moderate flexure. A patent application has been filed.

Additional comments:

1. There is reason to believe the acoustic device could be used in a communication system for gas masks.
2. It will likely be necessary to provide an operating frequency range greater than 2KHz for a reliable voice communication system. The transducer is one part of a system with many parameters that affect the frequency range. These system issues could be addressed in the gas mask application.
2. The acoustic device can function as a loudspeaker or a microphone.
3. In 1965 an experimental, two-way voice communication system was built and successfully demonstrated at Sarnoff, employing headphones modified with a microphone at one ear and a loudspeaker at the other ear. A similar arrangement may prove useful for gas masks.

Bill Rodda
Nov. 1, 1990